Hinc patriam sustinet

Instituto Superior de Agronomia
Universidade Técnica de Lisboa

IMPACT OF NITROGEN INTO THE ENVIRONMENT

A step on nitrogen footprint calculation in Lisbon, Portugal

Vitória Maria Pereira Gonçalves

Dissertação para obtenção do Grau de Mestre em

Engenharia do Ambiente

Orientador: Doutora Cláudia Saramago de Carvalho Marques dos Santos Cordovil

Co-orientador: Doutora Amarilis Paula Alberti de Varennes e Mendonça

Júri:

Presidente: Doutora Elizabeth da Costa Neves Fernandes de Almeida Duarte, Professora Catedrática do Instituto Superior de Agronomia da Universidade Técnica de Lisboa**.**
Vogais: Doutora Amarilis Paula Alberti de Varennes e Mendonça, Professora Catedrática do Instituto Superior de Agronomia da Universidade Técnica de Lisboa;
Doutora Cristina Maria Nobre Sobral de Vilhena da Cruz Houghton, Professora Auxiliar da Faculdade de Ciências da Universidade de Lisboa;
Doutora Cláudia Saramago de Carvalho Marques dos Santos Cordovil, Professora Auxiliar do Instituto Superior de Agronomia da Universidade Técnica de Lisboa;
Doutora Corina Luísa Videira de Abreu Fernandes Carranca, Investigadora Auxiliar do Instituto Nacional de Investigação Agrária e Veterinária, I.P.

Lisboa, 2013

Resumo

O uso de fontes antropogénicas de azoto (N) em alimentos e produção de energia têm impactos negativos, devida à acumulação de N reactivo no ambiente e consequentes efeitos cascata. Com o objectivo de quantificar a Pegada de Azoto para Portugal foi utilizado o modelo proposto por Leach et al (2012). Este modelo – Calculador de Azoto – foca-se no consumo de alimentos e energia, usando uma média de dados *per capita* para cada País. A Pegada de N calculada para Lisboa, Portugal foi de 23,5 kg N *per capita* por ano. As perdas de N para o ambiente são mais elevadas no consumo de alimentos do que no consumo de energia. Através deste estudo os consumidores Portugueses conseguirão perceber de que forma os seus hábitos influenciam as perdas de N para o ambiente.

Palavras-chave: Ambiente; consumo; energia; pegada de azoto; perdas de azoto.

Resumo Alargado

O azoto (N) é um dos elementos mais importantes na Terra, constituindo 78% da atmosfera. Os compostos formados pelo N podem ser não reactivos (N_2) ou reactivos (Nr). A transformação de N_2 em Nr, de fontes antropogénicas, tem levado à contaminação da água potável, lagos, rios e oceanos com nitratos (Godfray, 2012). Os compostos reactivos possuem uma elevada mobilidade que, encontrando-se em excesso, podem causar impactos negativos no ambiente, nomeadamente nos solos, águas, ar, provocar alterações na biodiversidade e no equilíbrio dos gases de efeito de estufa, gerando o fenómeno de N em cascata (Galloway, 1998). Na realidade, os hábitos alimentares das populações são indirectamente responsáveis pela perda de N, na medida em que a produção de alimentos é a principal causa da produção de Nr (Chatzimpiros and Barles, 2013).

Recentemente Leach et al. (2012) desenvolveram a primeira de três ferramentas que irá unir o sistema N-Print capaz de calcular as perdas de Nr para o ambiente, chamada Calculador de Azoto. Este modelo permite calcular a pegada de N para um País em Kg *per capita* por ano, contabilizando todas as perdas de Nr libertadas através da recolha de dados sobre os hábitos de consumo individual de alimentos e energia.

O consumo de alimentos reflecte as perdas de N ao longo de todo o processo de produção e consumo, contabilizando desde o fertilizante aplicado à cultura, resíduos, transporte e todas as outras perdas de Nr que possam ocorrer durante o processo.

O consumo de energia reflecte as perdas de Nr através das emissões de NO_x por queima de combustíveis fósseis. A pegada de energia está dividida em três partes: habitação, transportes e bens e serviços.

O objectivo deste trabalho foi calcular a pegada de N para uma região específica de Portugal, adaptando o inquérito proposto por Leach et al. (2012) para hábitos de consumo Mediterrânicos. Este trabalho representa o primeiro passo para o cálculo da pegada de N em Portugal, tendo sido escolhida a região de Lisboa como a amostra representativa.

Foram realizados cem inquéritos a indivíduos de nacionalidade Portuguesa, incluindo homens e mulheres com diferentes idades, em diferentes locais tais como áreas comerciais, zonas turísticas, áreas residenciais e de escritórios. O inquérito começou com questões relacionadas com o sexo e a idade, as seguintes perguntas foram direccionadas para os hábitos de consumo de alimentos (carne de aves, carne

de suíno, carne de bovino, leite, manteiga e iogurtes, queijo, peixe e marisco, gorduras animais, carne de carneiro e cabra, ovos, cereais de trigo, arroz, outros cereais, massa, fruta, feijão e grão, batata, frutos secos, azeite e azeitonas, legumes cozinhados, legumes frescos, açúcar e adoçantes, óleos vegetais, especiarias, vinho, bebidas brancas, café e chá, cerveja e refrigerantes) e por fim foram questionados os hábitos de consumo de energia tais como o consumo de energia eléctrica e gás e uso dos diferentes tipos de transporte (avião, transportes públicos, carro e mota).

O cálculo da Pegada de N para os alimentos e para a energia foi baseado nas fórmulas propostas por Leach et al. (2012). As porções que os indivíduos consomem em média por refeição utilizadas neste trabalho correspondem às porções definidas por Leach et al. (2012) para a Holanda. Para a obtenção dos valores do fornecimento de alimentos e proteínas recorreu-se à base de dados da FAO para Portugal.

No que diz respeito à energia consumida na habitação, foram utilizados dados de Itália (média de energia consumida e respectivo factor de emissão) para o cálculo da energia eléctrica considerados por (Leach and Galloway, 2011). Para o gás natural foram utilizados os dados da Holanda divididos por 10 (TWFB, 2013) e para o gás de botija foi consultada a empresa GALP. De acordo com o INE (2011) a população portuguesa é cerca de 10,562,178 e o número de famílias corresponde a 4,043,726.

Para o cálculo da energia nos transportes foram utilizados os dados da Holanda (Leach et al., 2012), excepto para os veículos motorizados de duas rodas que foram utilizados os de Itália (Leach and Galloway, 2011). De acordo com a Marktest (2013) apenas 23% da população portuguesa viaja de avião, este dado foi tido em conta.

Após a aplicação da fórmula proposta por Leach et al. (2012) para o cálculo da média da pegada de N para a energia foi efectuada a soma das médias das pegadas de N de cada sector de energia.

O consumo de bens e serviços contribui de forma indirecta para as emissões de Nr para o ambiente. Os bens correspondem a roupas, móveis, electrodomésticos, ferramentas, equipamentos de lazer, entre outros. Os serviços dizem respeito a abastecimento de água, correios, serviços hospitalares e serviços de lar. É através destes sectores que o azoto é libertado para o ambiente a partir da queima dos combustíveis fósseis. Devido à sua complexidade de quantificação e inexistência de factores de emissão específicos, para este trabalho foram considerados os valores da Holanda descritos por Leach et al. (2012).

Após efectuados todos os cálculos chegou-se à conclusão de que a média da pegada de N para Portugal corresponde a 23,5 Kg *per capita* por ano, em que a média da pegada de N os alimentos é 22,87 Kg *per capita* por ano e a média da pegada de N para a energia é 0,65 Kg *per capita* por ano. Os indivíduos entre os 31 e os 40 anos de idade possuem a pegada de N mais elevada (24.57 Kg N *per capita* por ano) e os indivíduos entre os 41 e os 50 anos de idade possuem a mais baixa (22.96 Kg N *per capita* por ano). A pegada de N correspondente aos indivíduos do sexo masculino é muito similar à do sexo feminino (23.45 Kg N *per capita* por e 23.58 Kg N *per capita* por ano, respectivamente).

Este estudo permite aos consumidores e produtores perceberem, de acordo com os seus hábitos, a quantidade de perdas de Nr para o ambiente, alertando-os e sensibilizando-os para a necessidade de alteração dos seus comportamentos de consumo e práticas de produção. Assim será possível minimizar os impactos negativos, que a longo prazo seriam catastróficos para a Terra.

Abstract

The use of anthropogenic sources of nitrogen (N) in food and energy production has negative impacts, due to the buildup of reactive N in the environment and subsequent nitrogen cascade effects. With the objective of quantifying Nitrogen Footprint to Portugal was used the model proposed by Leach et al (2012). This model – The Nitrogen Calculator – focuses on the consumption of food and energy using an average *per capita* data for each country. The N Footprint found for the restricted area of Lisbon, Portugal was 23.5 Kg N *per capita* per year. Losses of N to the environment are higher for the food consumption than for the energy consumption. Through this study the Portuguese consumers will be able to understand the way their habits determinate the losses of N to the environment.

Keywords: Consumption; energy; environment; nitrogen losses; nitrogen footprint.

Índice

List of tables and figures

List of abbreviations

N – Nitrogen

Nr – Reactive nitrogen

NO_x – Nitrogen oxides

N_2O – Nitrous oxide

NH_3 – Ammonia

NH_4^+ - Ammonium

NO_3^- - Nitrate

NO_2^- - Nitrite

NO_2 – Nitrogen dioxide

1 Introduction

Nitrogen (N) is one of the most important elements on earth, namely as a major component of amino acids and nucleic acids. Although 78% of the atmosphere is composed by the N harmless inert gas N_2, this form of N is not available for the majority of species and is the least readily available for living organisms (Erisman et al., 2008; Galloway et al., 2003). N compounds can be grouped in two different types: the nonreactive N which is the N_2, and the reactive N (Nr) which includes all the other N biological, photochemical and radioactive compounds present in the Earth's atmosphere and biosphere (Galloway et al., 2003). The reactive forms of N include nitrogen oxides (NO_x), nitrous oxide (N_2O), ammonia (NH_3), nitrate (NO_3^-), ammonium (NH_4^+), nitrite (NO_2^-) and nitrogen dioxide (NO_2), when they are in excess in the environment they threaten air, water, and soil quality and lead to changes in biodiversity and ecosystems as well as greenhouse gases balance (Galloway et al., 2008). Although many research and policy efforts have been made to call attention and minimize N problems, reality shows that the over emission of Nr to the environment is still an unsolved pollution problem (Sutton, 2012). The Eurostat yearbook Europe in Figures, published by the European Commission, does not yet give proper attention to Nr emissions to the environment (EF, 2012).

1.1 Nitrogen in perspective

Before the Industrial Revolution, Nr did not accumulate in the environment because microbial N fixation and denitrification processes were mutually compensated (Ayres et al, 1994, cit by Galloway et al, 2003), as Nr was only produced from lightning and biological N fixation (Galloway et al., 2003). However, in the mid 18th century, the Industrial Revolution was the turning point in man's relationship with the environment, as it dramatically improved every aspect of human life. The most dramatic impact of the Industrial Revolution was the world's population growth, due to major discoveries in medicine and changes in living standards which allowed for a reduction in mortality and increased rate of fertility. At the beginning of the Industrial Revolution world's human population grew by about 57 percent. After, a dramatic growth beginning in 1950 (above 1.8% per year) led to the need for increased food production which resulted in the industrialization of agriculture brought about by the Green revolution (UN, 2010). The rate of human population growth peaked in 1964, at about 2.1% per year. During the 20th century, the world population growth would take exponential proportions, growing to six billion people just before the start of the 21stcentury (UN, 2010).This population explosion during the 20^{th} century, exponentially increased the need for food and energy, both resulting from natural and man-made resources, but also increased exponentially the waste generation, towards an out of control situation (Carson, 1962).

1.2 Solving over population and food scarcity

Feeding the world's population was only possible due to the invention of the Haber-Bosh process, back in the early 19's, which allowed the synthesis of cheap mineral N fertilizers from N_2 and energy, boosted the use of N in agriculture and solved many of the hunger problems in the world, by enabling the Green Revolution (Evenson and Gollin, 2003, Sutton et al., 2011). Without this technique, half of the people in the world would not be alive (Erisman et al., 2008). But, this advance in agricultural production did not come without costs, as N became the single most important pollutant deriving from agriculture (Godfray, 2012). In fact, the human alteration of the N cycle, by transforming many of the unreactive N_2 into reactive forms of N, led to the pollution of the hydrological cycle with NO_3^- and thus to the contamination of drinking water, lakes, rivers and oceans (Godfray, 2012), and is projected to increase (Galloway et al., 2003). Nr interacts with elements of the environment to create smog – increasing levels of ozone at the Earth's surface, acidifying the water and weakening the upper-atmosphere ozone layer. Nr molecules can convert rapidly from one form to another and move from one environmental system to another, generating the N cascade phenomenon (Galloway, 1998). The endpoint of the cascade is the emission of N_2 and N_2O, the latter responsible for climate change (Erisman et al, 2011), meaning that man is now the ultimate responsible for the global change (Erisman et al., 2011). The disruption of N cycle has dramatic effects on climate change and agriculture is a major responsible (de Vries et al., 2011). Moreover, the N cycle is probably the most altered amongst the basic elements cycles (Galloway et al., 2008).

1.3 Too much reactive nitrogen

Taking into account that the need for more food and energy has been the driver for the increased production of anthropogenic Nr from N_2, and that total Nr production exceeds the utilization and the natural processes of converting Nr back into inert N2, the reactive forms of N tend to accumulate in the air, water, soil and biomass (Galloway et al., 2008). Therefore it is possible to state that food and energy are the main responsible for the Nr accumulation on Earth. In fact, Galloway et al (2008) referred that ~77% of the anthropogenic Nr derives from food production, ~16% from energy production and only ~9% for industrial uses. Thus, fertilizer use by farmers directly affects the N cycle and is not always adequate. Furthermore, negative effects and costs do not influence farmer's behavior (Godfray, 2012). One of the activities with a greater pollution potential is animal production, which consumes about 85% of the total N used in crops produced or imported in EU (Sutton et al., 2011). Nearly 60% of the world's agricultural land is used for beef production, yet beef represents 24% of the world's meat consumption and accounts for less than 2% of the calories consumed throughout the world. In contrast, poultry accounts for 34% of global meat consumption and pork accounts for 40%. Both poultry and pork production uses less than two million square kilometers of land each (Boucher et al., 2012). If we consider some food commodities, the total Nr fluxes from ruminant meat are ~200 g per Kg meat produced, ~50 g N per Kg of pig and poultry meat and ~ 15 g N for dairy products. All crops have a much lower flux of Nr than animal products (Lesschen et al., 2012). Average EU citizen eats more meat and animal products that necessary in a healthy diet and, if Europeans obtained their protein from plants rather than from animal meat, only 30% of the crops would be needed and N pollution would be reduced by 70% (Sutton, et al., 2011). If US population adopted the typical Mediterranean diet with a meat consumption of ~ 6.3 Kg per capita per year, inorganic N fertilizer used would decrease by ~ 65 % (Galloway et al., 2003). Unfortunately farmers and consumers do not make a cost benefit analysis when it comes to production and consumption.

1.4 Human diet and nitrogen

Ultimately, eating habits of the populations are indirectly the main responsible for N cycle breakout, as food production is the main cause for anthropogenic Nr production (Chatzimpiros and Barles, 2013). Despite the increasing awareness, consumption habits do not improve. For example, worldwide, per capita meat consumption increased from 41.3 Kg in 2009 to 41.9 Kg in 2010. While people in the developing world eat 32 Kg of meat a year on average, in the industrial world people eat 80 Kg a year (www.worldwatch.org, 2013). During the second half of 20th century population increased by 70% and per capita consumption of meat and milk raised 50% and 5% respectively (WHO, 2003). High productivity is very often accompanied by high Nr losses into the environment which enters the N cascade. Also, N losses depend on human, especially urban, diets. Thus, it is important to integrate measures to reduce Nr emissions from production with urban consumption habits (Chatzimpiros and Barles, 2013).

1.5 Drawing public attention

Indicators seem to be the best way to draw the attention of the general public and to increase knowledge about a particular problem. Back in 1992, William Rees and Mathis Wackernagel (1996) created the concept of ecological footprint analysis and so far several footprints have been put to practice. For example, the carbon footprint invented by Arjen Hoekstra in 2002, and the later integration of footprints into the “Footprint Familly” by Galli et al. (2011). Xue and Landis (2010) integrated to the life-cycle analysis of N and P from food consumption patterns into the potential for eutrophication, and showed that different food groups have different N impacts, which are not consistent with their carbon footprint. Within the same context, Billen et al. (2009 cit by Chatzimpiros and Barles, 2013), specified the term foodprint to express in hectares the agricultural area needed to supply food to the city of Paris.

1.6 Launching the N-PRINT

More recently Leach et al. (2012) developed the first of three tools which will put together the N-PRINT system for the calculation of the Nr losses into the environment from both individual (consumer) and collective (producers and society) behavior towards consumption and production practices and policy impact on these losses. This first tool is called the N –CALCULATOR (Leach et al., 2012). The N –Calculator is a personal footprint model to estimate the total amount of Nr lost into the environment due to individual consumption of food and energy. The N-Calculator accounts not only for the losses resulting from food and energy consumed, but also for the losses resulting from all the activities upstream. The upstream losses include all the Nr released into the environment from production of food, energy, goods and services (Leach et al., 2012).

The calculation of N footprint from a type of food requires the knowledge of the average consumption data of that food and of its N content, expressed as protein content. Protein supply represents the total available and not necessarily the amount consumed because it does not account for wastes. Food waste must be subtracted from the total N supply, to calculate the real amount of N consumed. All the information presented by Leach et al. (2012) was collected from the FAOstat website, except the data of food waste which was reported by Kantor et al. (1997).

In order to calculate the upstream impact of food and energy production on the Nr losses into the environment, Galloway et al. (2007) presents the so called Virtual N factors. "More specifically, Virtual N includes all Nr losses related to an initial investment of N fertilizer into a system, such as fertilizer not incorporated into the plant, crop residue not part of the food product, feed not incorporated into the animal product, and all of the plant or animal products that are lost in processing and food preparation. Once all of the inputs and releases are summed, the N consumed as food can be subtracted out; the remaining amount is the Virtual N. In this case, Virtual N for food does not include the Nr released to the environment as a result of transportation or other energy use during the food production process" (Leach et al., 2012 sic.). Using the N-Calculator model, the N footprint for each food type is determined by summing Nr released by the food consumed to the respective Virtual N which corresponds to upstream Nr losses. Each personal N footprint corresponds to the sum of all the food categories footprints.

Energy consumption is the other part of the N footprint within the N-Calculator, and relates to Nr losses through NOx emissions by fossil fuels burning. Energy footprint is divided into three parts: housing, transportation and services. The calculation of energy N footprint is done by a combination of two approaches: bottom up and top down. Bottom up approach is the combination of activity data and the respective emission factor (e.g. km driven in a car and amount of NOx emitted per km driven). This approach is used to calculate N footprint of activities which have well known emission factors such as electricity. The average activity data are collected for a country and individual energy footprint is calculated from an energy usage questionnaire (N-Calculator). Top down approach is used for energy N emission from indirect sources, for example during manufacture of a car used by the consumer. This provides a solution for estimating the Virtual N energy footprint for activities without an emission factor (section D of figure 2).

To run the N-Calculator in order to estimate personal N-footprint, a survey is available on the website www.n-print.org. Questions consist of information about portions of each food type consumed by an individual, on a weekly basis. Housing, transportation and goods and services are also inquired on a weekly, monthly or yearly basis, considering usual consumption. All data input is then extrapolated to a yearly basis, compared to the average country values and personal footprint calculated. So far, the N-Calculator is only available for reference data from the USA, Germany and The Netherlands. However, consumption patterns in these countries do not apply for all EU countries, namely for Mediterranean ones. This applies for both food and energy, as there are differences in the diet and in energy spent. For example, in the Mediterranean basin food consumption varies from Central and Northern Europe standards, and energy use is also different, for example due to warmer climates and increased daylight. However, the greatest contribution for N-footprint comes from food consumption (www.n-print.org), and here too consumption patterns differ from south to north of Europe, and from The United States of America.

1.7 The Mediterranean diet and nitrogen footprint

There are three types of eating habits which have been related to health and longevity. They are the Chinese, the Japanese and the Mediterranean diets. The Mediterranean diet has been pointed out as the healthiest one on the planet (Gingliano et al., 2001). This fact is supported by epidemiological studies which prove that inhabitants of countries from the Mediterranean basin have less chronic diseases and a higher live expectancy (Serra-Majem and Bartrina, 2002). The Mediterranean diet has been defined as the food habits of Greece and southern Italy. However, it varies in other southern European countries, in western Asian countries and northern African coast, thus, there are as many Mediterranean diets as there are countries in the Mediterranean basin (Helsing and Trichopoulou, 1989, Trichopoulou, et al. 2003). It was even claimed that Portugal had the best diet amongst all Mediterranean countries, due to the lowest percentage of saturated fatty acids and animal calories (Cruz, 1997).

The southern European countries eating habits are just variations from a theoretical common model. According to Mahan and Escott-Stamp (2007), this eating model is based on diversity and balance. Traditional Mediterranean diet has 7 main components: high ratio of monounsaturated fatty acids, high consumption of vegetables, high consumption of cereals, high consumption of fruits, low consumption of meat and meat products, moderate consumption of milk and dairy products and moderate wine consumption (Trichopoulou, 2003). Dishes include large amounts of mass and whole grains. Soups and salads are consumed in large quantities, and recipes include a reliance on plant foods such as vegetables, potatoes, rice, beans, nuts, olives, fruits, and olive oil along with some cheese, yogurt, fish, poultry and eggs. Milk products are consumed with moderation, but cheese and yogurts consumption can be occasionally high. Meat and fish are used with relative modesty despite the fish being frequently eaten in coastal areas. Wine is consumed in moderation, usually during meals in many countries of the Mediterranean basin (Mahan and Escott-Stamp, 2007). Most of the foods on the plan are fresh, seasonal and they are not processed, and preparations tend to be simple.

The objective of this work was to calculate the N Footprint for a specific region in Portugal, Lisbon, by adapting the survey proposed by Leach et al (2012) model according to Mediterranean consumption habits, which differ in some cases from the existing parameters for the Unites States, for Germany and the Netherlands (www.n-print.org). This work represents the first step on N footprint calculation in Portugal.

2 Materials and methods

This work was the first step on the calculation of N footprint in Portugal, and Lisbon capital was defined as sampling region. One hundred surveys were made randomly, to individuals of both sexes, and different ages. The survey was performed in different days and in different places of the city, including commercial areas, touristic places, office neighborhoods and residential areas. The surveys were performed in the oldest neighborhoods of Lisbon, in new residential parts of the city, as well as in the commercial and industrial surroundings, to cover different environments of the city. People inquired were all Portuguese. The survey began with personal questions to determine the range of ages. Then, the second part of the survey consisted of questions about food consumption habits, and the final part of the survey consisted of questions about energy consumption habits, such as the use of several types of transportation, and household equipment.

To support these modifications to the original survey proposed by the Leach et al. (2012) model, Portuguese statistical data was collected.

2.1 Personal identification

People surveyed were chosen at random on the street. The survey begun with a brief presentation of the problem of N and the need to assess your footprint in order to introduce the subject and to get the person’s attention, so that the answers were as reliable as possible. After, the second part of the survey took place.

2.2 Calculation of the Nitrogen Footprint from food

The calculation of the N Footprint was based on the questions and formulas proposed by Leach et al (2012), but the model was adapted to the Mediterranean food consumption habits, especially the ones in Portugal.

The portions used in this survey, correspond to the Portuguese data and are described in Annex II (Leach et al., 2012). The missing portions were completed by using average Portuguese data, recommended by the Portuguese Nutritionists Association (APN, 2013) and by the Sports life magazine (SL, 2013). For example for cereals, including breakfast flakes, we considered a portion of 50 g. Although this value was based on the 30 g daily portion recommended by the manufacturer, it is known that the real size of the portions generally differs from the recommendation. It was also assumed that a portion of rice is equal to that of paste since one cereal replaces the other in a meal. The same reference portions for drinks were used for wine and soft drinks.

According to Leach et al. (2012), to calculate N footprint from food consumption, FAO database was used in order to obtain the values for food supply, expressed in Kg per person per year, and proteins supply in g per person per day (FAOstat 2009 data). Protein data was converted to Kg per person per year, and multiplied by 0.16 factor, to calculate N supply from proteins (Leach et al, 2012). The loss of N related to food consumption was calculated by multiplying the food losses from each type of food, calculated by Kantor et al (1997), to the correspondent values of N supply as described above. Data for some types of food loss are not available in Kantor et al. (1997) so, these values were not taken into account to the calculation of the N Footprint. However, for some commodities like potatoes, we considered Italian losses (Leach and Galloway, 2011). These data is available in Annex IV. To calculate individual's N-footprint, data was input into the formula proposed by Leach et al (2012) (figure 1).

To calculate the Virtual factors of N for each type of food, included in B section of the scheme, the respective total N loss was divided by the total N available which allowed finding the quantity of Nr lost to the environment by unit of consumption of N (table 3). It was not possible to obtain all the values of the factor of virtual N because there was a lack of data of the percentage of N lost in the food waste.

The total average *per capita* N Footprint was found by summing the N Footprint of all the food categories according to Leach et al (2012) formula.

2.3 Calculation of the Nitrogen Footprint from energy

Consumption of energy is related to the fossil fuel combustion and the resulting NO_x emissions from the domestic sector (kitchen, heating, cooling), from transports (cars, airplanes, public transportation) and from goods and services (energy used to provide goods and services). To calculate the N Footprint the following schematic formula (Leach et al., 2012) was used (figure 2).

2.3.1 Housing

Average energy consumption and respective emission factor for electricity was based on data obtained in Italy (244.40 kwh/month, 0.000017 Kg N/kwh) (Leach and Galloway, 2011). We considered this emission factor because Italy has similar food and housing standards as Portugal. The diet is essentially Mediterranean, and climate and daylight approximate, thus leading to approximate patterns of consumption. Multiplying both values, an average *per capita* bottom-up N Footprint for electricity was obtained. This value represents the real value of consumption in a country. The individual energy N footprint was calculated by multiplying the value obtained on the survey by the emission factor. Average N emission in Portugal was obtained by multiplying the average energy consumption by the number of families in Portugal (about 4,043,726, according to INE, 2011) and by the latter emission factor. Portuguese population is about 10,562,178 people (INE, 2011). To obtain the average per capita N Footprint of top-down energy, the national value of N emission was divided by the number of people and then, average *per capita* N footprint of bottom-up energy was subtracted. The sum of the averages *per capita* of The N Footprint of both bottom-up energy and top-down energy allow obtaining the value of the average *per capita* of the N Footprint for energy.

For the calculation of natural gas N emission, the average values of energy consumption and the respective emission factor were modified from Dutch data (133 kwh/month, 0.000495 Kg N/kwh). However these values are ten times higher than in Portugal (TWFB, 2013) due to the climate which determines a much higher use of gas for heating. So, values were divided by ten, since the emission factor is proportional to the average of energy consumption.

In Portugal, besides electricity and natural gas, there is another representative source of energy which is the use of gas cylinder as a substitute for natural gas in houses which are not linked to the city gas network. GALP (Portuguese Gas provider) was consulted to know the exact amount of gas in each 13 Kg gas cylinder, which is 4.80m^3. As the emission factor is proportional to the average energy consumed, the calculation of the emission factor for cylinder gas resulted from the multiplication of the emission factor for natural gas by the average value of energy consumption for gas in cylinder and subsequent division by the average value of the energy consumption of natural gas.

2.3.2 Transportation

The same emission factors as in Netherlands (Leach et al., 2012) were used for transportation, except for motorcycles. In this case Italian factors (Leach and Galloway, 2011) were considered to be more representative of Portuguese consumption standards. However in Italy the traffic of motorcycles is higher than in Portugal because Italy has six times the Portuguese population so, both the emission factor and the average value of energy consumption were divided by six (table 4).

Concerning private cars emission factor a value of 0.0009 Kg N/km was used for gasoline and of 0.00015 Kg N/km for diesel.

National N emissions were calculated by multiplying the average value of energy consumption in Portugal by the emission factor and by country population, except for the airplanes. As only 23% of the Portuguese population travels by plane (Marktest, 2013) this source of N emission value was multiplied by 0.23.

2.3.3 Goods and Services

Consumption of goods and services also contributes to an indirect Nr emission to the environment. Goods are, for example, cloths, furniture, tools, amusement equipment, etc. Services are, for example, water-supply, mail services, hospital services and recreational services. Fossil fuel is the main source of N emission from services. As this sector shows great complexity in quantification of specific emission factors, the Dutch values considered by Leach et al (2012) were used in this study.

3 Results

3.1 Modification of the model survey

In the survey we included several of the typical ingredients from Portuguese gastronomy, which are typical of the Mediterranean diet. Several items were added to the initial model list of food and ingredients. In Portuguese gastronomy, cooked vegetables are an important part of the daily meals, due to the Portuguese habit of eating vegetable soup and cooked vegetables with meals. Many of the traditional dishes include potatoes, cabbages, carrots, turnip and beans. Tomato is also used in many preparations but the different varieties of cabbages are the most important on the diet. These main courses are daily accompanied by rice or/and potatoes. Ingestion of carbon hydrates represents 62% of food consumption in Portugal (BAP, 2006). The different food types included in the survey are presented in Table 1.

Fresh vegetables are normally served as salads to accompany meals or even as the main course by adding other ingredients to complete the meal. Portuguese consumption of vegetables was, in 2004, 107.5 Kg per capita (INE, 2011).

Portugal has many olive groves as the Portuguese consume olives, as an aperitif before the meals or used during the meal preparation. Portuguese consumption per capita was 0.9 Kg in 2010 (INE, 2011), corresponding to a daily per capita of 17 g (BAP, 2006). Rice is also often included in Portuguese diet, and it alternates with pasta. Portuguese consumed 15.8 Kg rice per year per person (INE, 2011). Butter is generally consumed at breakfast with bread, and yoghurts are generally consumed between meals as a replacement for the English afternoon tea. Consumption was respectively 1.7 Kg and 21.3 Kg per person in 2011 (INE, 2011).

Portugal is known worldwide as a wine producer. In Portugal wine is produced all over the country, with different characteristics according to the region and soil and climate conditions. For example, in the Douro region (UNESCO PATRIMONY) and Alto Alentejo region. Portuguese people usually drink a glass of wine during the main meals, both lunch and dinner, as well as in festivities. Yearly per capita, wine consumption is 44.2 L (INE, 2011). Wine is also often used to make refreshments such as the famous sangria. Cold drinks were also considered in the survey due to the important consumption during meals, at afternoon tea and with the so called white spirits in night live. Note that wine consumption starts at adult age. Soft drinks represent 223.8 mL per year per person, and other alcoholic drinks except wine 290.2 mL per person (INE, 2011). Portugal decreased the consumption of wine and beer respectively by 13 and 11% between 2011 and 2012 (www.kantarworldpanel.com acceded in March 2013) and increased by 22.1% of tea consumption on the same period.

3.2 Average nitrogen footprint

In Lisbon, the average N Footprint for men and women was similar, and there was no significant difference between N footprints within the different age classes surveyed (figure 3). Different age groups conditioned the values of the N Footprint. Persons with 31 to 40 years old had the highest N footprint (24.57 Kg N/capita/yr). This could be due to the low number of persons enquired which had these ages, leading to an error. However this result should be confirmed in further studies. Between the age of 41 to 50, N footprint was the lowest (22.96 Kg N/capita/yr). People older than 50 of age the N footprint is 23.60 Kg N/capita/yr. Bellow 20 years and between 21 and 30 had similar footprints (23.30 Kg N/capita/yr and 23.43 Kg N/capita/yr respectively). Despite the footprint tendencies presented, these results are not statistically different ($p<0.05$).

Men's estimated N footprint was 23.58 Kg N/*capita*/yr and for women it was 23.45 Kg N/capita/yr (figure 4). Some difference between the two sexes results from the different N footprint in transports between men (0.18 Kg N/capita/yr) and women (0.13 Kg N/capita/yr). N footprint resulting from food sector was similar between women (22.94 Kg N/capita/yr) and men (22.76 Kg N/capita/yr).

Average N footprint calculated was 23.5 Kg N/capita/yr. Average N footprint from food consumption was 22.87 Kg N/capita/yr and N footprint from energy consumption was 0.65 Kg/capita/yr. In figure 5, there is a comparison between N footprints in Lisbon, and the national N footprints in USA and The Netherlands.

Concerning the N emission from housing energy, we had a new parameter which was the use of gas cylinder. According to the survey, the per capita average number of cylinders used was 0.26. This value was multiplied by the average content of a gas cylinder (4.8 m^3) to know the total amount of gas spent per capita.

Emission factors for fuel use and thus for emissions from transportation were calculated according to the proportion of vehicles using gasoline or diesel. From the survey 41% of the individuals use diesel and 34% use gasoline. The global emission factor from transportation was calculated by multiplying 0.45 to the emission factor of gasoline and by 0.55 tor the emission factor of diesel.

4 Discussion

Persons were not generally receptive to the problems of environmental impact of N, as the majority does not even know what N is. To get them to spend a little time to answer to the surveys, we had to call their attention with the fact that this was a work for the university. Another problem that we faced was that people do not have information on the number of KWh and m^3 spent per month in household. However, to increase information reliability, we decided to ask them about the value in euros they paid per month for gas and electricity. People under the age of 20 years were surveyed when accompanied by family members which could give this information, since below 20 years they still live with their parents and have no responsibility for the payment of household bills.

According to Leach et al (2012) (figure 5), the average *per capita* N Footprint in the United States of America is 41 Kg N/yr, including 29 Kg N/*capita*/yr from food and 12 Kg N/*capita*/yr from energy. The same authors presented the N footprint for The Netherlands, which was 25 Kg N/yr, including 23 Kg N/capita/yr from food consumption and 2 Kg N/capita/yr from energy consumption. As shown in figure 5, *per capita* N footprint in Lisbon area sampled is lower than in the USA and in the Netherlands. There is a big difference between Portugal and USA in energy and food consumption, culture and consumer habits are different. Energy sources were the main reason for such a different contribution to N emissions between Portugal and Netherlands. Although food consumption habits in Lisbon (Portugal) and in the Netherlands produced similar N footprints, we may justify the higher energy emission by the higher use of heating power in The Netherlands. Climate is probably the main driver for a higher N footprint within these two European countries.

Amongst the food types within the survey, meat and cereals are the greatest contributors for N Footprint increase. It is important to emphasize that the main losses of N to the environment occur when the N is applied directly to the crops is not used by these crops. This fact occurs when the use of N fertilizers is excessive. The N can still be lost by leaching and/or surface run-off, denitrification and nitrification, by emissions to the air on the form of NH_3 and microbial immobilization.

Correct N fertilization on an economic and environmental perspective should be done, considering the N exported by crops, desired and potential crop production, soil characteristics, expected precipitation and temperature range. The residual N in the soil and the mineralized N from SOM should also be taken in to account as well as the residue from previous crops and other exogenous organic materials (Cordovil, 2004). By implementing a cost benefit behavior may be it will be possible to reduce the N Footprint from food production sector.

Curiously, 5% of the individuals inquired did not have sewerage system with tertiary treatment of sewage, which should be improved.

The US energy footprint was 12 Kg N/capita/yr (3 Kg N/capita/yr for housing, 6 Kg N/capita/ yr for transportation and 3 Kg N/capita/yr for goods and services). The Netherlands energy footprint was 2 Kg N/capita/yr (1 Kg N/capita/ yr for housing, 1 Kg N/capita/ yr for transportation and 0.5 Kg N/capita/yr for goods and services).

Despite the differences between the countries sampled, food consumption is doubtless the sector which most contributed to N Footprint. In Lisbon (Portugal), food sector was followed by goods and services with 0.5 Kg N/capita/yr emission. Transports contribute with 0.15 Kg/capita/yr. The electricity and gas consumption in what concerns the household only contributed 0.002 Kg N/capita/yr to the values of N Footprint.

In what concerns to the domestic energy consumption it is strange that the value of the N Footprint was 0.002 Kg N/capita/yr. However, the possible justification to this situation is the fact that the climate in Portugal is temperate and so the Portuguese people do not spend energy in heating. The individuals inquired said they used the energy to illuminate the house, for cooking and for personal hygienic. Besides the great majority of Portuguese people live in small apartments, each family has an average of 2.89 persons and those may be the reasons for the value of the N Footprint.

In the case of transports, the car contributes to the higher N Footprint (0.08 Kg N/capita/yr), The Portuguese do about 203 Km per week. The airplane also contributes to the higher N Footprint with 0.07 Kg N/capita/yr, the reason for these values owes to the high factor emission of this mean of transportation. The N footprint in this sector was very low. Only 23% of the Portuguese population travels by airplane, which is a low percentage. The plane is a means of transport with the highest N emission factor, which could be one of the reasons for such a difference.

Goods and services most contributed to the N Footprint (0.5 Kg N/capita/yr) although is a virtual value since it was calculated from the Netherlands. However it is supposed to be very close the one expected for Portugal.

The value of the N Footprint in the energy sector is underestimated for two reasons. At first because according to Leach et al (2012) the imports were not included which implies that transport and production are underestimated. Secondly, because the emission factors used were not the ones of Portugal.

5 Conclusions

In order to increase reliability of the results, more surveys must be made in different areas of Portugal. More information related to the emission factors and average values of the energy consumption in Portugal are also needed. However, with the results obtained, it is possible to say that the Portuguese people have a high N Footprint in what concerns food consumption and a smaller N Footprint in the energy consumption. With these data the Portuguese consumers may understand the way their habits influenced their N Footprint and how to reduce it, minimizing the impacts of the loss of N to the environment.

In the food sector, a way to reduce the N Footprint consists in reducing for example the consumption of meat and cereals, making the option to consume more sheep and goat, fish, vegetables, beans and potatoes, meaning a return to the Mediterranean traditional diet. In the transports sector a way to reduce the loss of N to the environment is to shorten the use of airplanes, making an option, for instance, to travel by train or other mean of public transportation, and if possible also reduce the use of cars, shorten to travel by public transportation. The N emissions to the environment are smaller if diesel cars are used instead of gasoline cars. In the case of goods and services is advised to reduce the consumption of goods like clothes and decorative articles. This could help to reduce the N Footprint.

This study was made in Lisbon, Portugal by calculating the average values of the inquired. However, any Portuguese may answer the inquiry and insert his data in the excel sheet and calculate their N Footprint.

6 References

APN 2013. http://www.apn.org.pt acceded in March 2013.

Ayres, R.U., Schlesinger, W., Hand Socolow, R.H., 1994. Human impacts on the carbon and nitrogen cycles, in: Socolow, R.H., Andrews, C., Berkhout, R., Thomas, V., (Eds.), Industrial ecology and global change, E-Publishing Cambridge (MA): Cambridge University press, Cambridge, pp. 121-155.

BAP 2006. Balança Alimentar Portuguesa 1990-2003. (Portuguese Food Balance 1990-2003) INE eds. 6p. (Publication of the Portuguese national statistics institute).

Billen, G., Barles, S., Garnier, J., Rouillard, J., and Benoit, P. 2009. The Food-Print of Paris: Long term Reconstruction of the Nitrogen Flows imported to the City from its Rural Hinterland, Reg. Environ. Change, 9, 13–24.

Boucher, D., Elias, P., Goodman, L., May-Tobin, C., Mulik, K., Roquemore, S., 2012. Grade a Choice? Solutions for Deforestation – Free Meat. UCS (This report is available online in PDF format at www.ucsusa.org/deforestationfree).

Chatzimpiros, P. and Barles, S. 2013. Nitrogen food-print: N use related to meat and dairy consumption in France. Biogeosciences, 10, 471–481.

Cordovil, C.M.d.S, 2004. Dinâmica do Azoto na Reciclagem de Resíduos Orgânicos Aplicados ao Solo, ed. Instituto do Ambiente, Lisboa.

Cruz, J.A., 1997. Dieta mediterrânica e saúde. Revista Portuguesa de Nutrição. Centro de Estudos de Nutrição do Instituto Nacional de Saúde Dr. Ricardo Jorge. VII(2), 20-26.

Dreamstine, 2013. http://www.dreamstime.com (assessed in March 2013, used to do the cover)

EA 2012. Agricultural Statistics 2011, ed (Portuguese national statistics institute INE I.P). Lisboa, Portugal.

EF 2012. Europe in Figures. Eurostat Yearbook 2012. European Commission ed. (Available in pdf format online at http://epp.eurostat.ec.europa.eu/)

Erisman, J.W., Sutton, M.A., Galloway, J.N., Klimont, Z., Winiwarter, W., 2008. How a century of ammonia synthesis changed the world. J. Nat. Geoscience. 1, 636-639.

Erisman, J. W., Galloway, J., Seitzinger, S., Bleeker, A., Butterbach-Bahl, K. 2011. Reactive nitrogen in the environmental and its effect on climate change. Current Opinion in Environmental Sustainability 3, 281-290.

Evenson, R.E., Golin, D., 2003. Assessing the impact of the Green Revolution, 1960 to 2000. J. Sci. Commun. 300, 758-762.

Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B., Giljum, S., 2011. Integrating ecological, carbon and water footprint into a “Footprint Family” of indicators: Definition and role in tracking human pressure on the planet. J. Ecol. Indicators. 16, 100–112.

Galloway, J.N., 1998. The global nitrogen cycle: changes and consequences. J. Environ. Pollut. 102(S1), 15-24.

Galloway, J.N., Aber, J.D., Erisman, J.W., Seitzinger, S.P., Howarth, R.W., Cowling, E.B., Cosby, B.J., 2003. The nitrogen cascade. J. Bioscience. 53(4), 341-356.

Galloway, J.N., Burke, M., Bradford, E., Naylor, R.L., Falcon, W.P., Mooney, H.A., Gaskell, J., Oleson, K., McCullough, E., Steinfeld, H., 2007. International trade in meat—the tip of the pork chop. J. Ambio. 36, 622–629.

Galloway, J.N., Raghuran, N., Abrol, Y.P., 2008. A perspective on reactive nitrogen in a global, Asian and Indian context. J. Curr. Sci. 94(11), 1375-1381.

Gingliano, D., Sedge, M., Sepe, J., 2001. The Mediterranean diet: Origins and myths. N. Engl. J. Med. 344 (12), 904.

Godfray, H.C.J., 2012. The challenge of feeding 9-10 billion people equitably and sustainably. Proceedings of the 17th International Nitrogen workshop. Ireland. pp 384-390.

Helsing, E., Trichopoulou, A., 1989. The Mediterranean diet and food culture: A symposium. Eur. J. Clin. Nutr. 43(2), 1-92.

INE 2011. Instituto Nacional de Estatística. (Portuguese national statistics institute). Online access at www.ine.pt in March 2013.

Kantor, L.S., Lipton, K., Manchester, A., Oliveria, V., 1997. Estimating and addressing America’s food losses, ed. Department of Agriculture Economic Research Service: Food Review, United States.

Leach, A.M., Galloway, J.N., 2011. N-PRINT Workshop Report. The Royal Institution of Great Britain in London, UK. 3-4 December 2011. (available at www.n-print.org).

Leach, A.M., Galloway, J.N., Bleeker, A., Erisman, J.W., Kohn, R., Kitzes, J., 2012. A nitrogen footprint model to help consumers understand their role in nitrogen losses to the environment. J. Environ. Development. 1, 40-66.

Lesschen, J.P., Leip, A., Wagner, S., Westhoek, H.J., Oenema, O., 2012. The nitrogen footprint of European food production. Proceedings of the 17th International Nitrogen workshop. Ireland. pp. 398-399.

Mahan, K., Escott-Stumps, S., 2007. Krause's Food, Nutrition, and Diet Therapy, 12th ed. Pa: WB Saunders Co., Philadelphia.

MARKTEST 2013. National and International Market Surveys. (Online assess at www.marktest.com in March 2013).

Personal N Footprint Calculator, 2013. http://www.n-print.org/N-Calculator (assessed in March 2013).

Serra-Majem, L., Bartrina, J.A., 2002. Alimentación Infantil Y Juvenil. Estúdio en Kid, third ed. Masson, Barcelona.

SL 2013. Sports life magazine. (Online assess at www.sportslifemagazine.com in March 2013).

Sutton, M.A., 2012. An integrated approach to reactive nitrogen in the environment. Proceedings of the 17th International Nitrogen workshop. Ireland. pp 253-255.

Sutton, M.A., Oenema, O., Erisman, J.W., Leip, A., van Grinsven, H., Winiwarter, W., 2011. Too much of a good thing. J. Nat. 472, 159–161.

Trichopoulou, A., 2003. Adherence to a Mediterranean diet and survival in a Greek population. N. Eng. J. Med., 348(26), 2599-2608.

Trichopoulou, A., Costacou, T., Bamia, C., Trichopolous, D., 2003. Aderence to a Mediterranean diet and survival in Greek population. The New England Journal of Medicine 328(26), 2599-2608.

TWFB 2013. The World Fact Book, 2013-14 ed Central Intelligence Agency, United States. ISSN 1553-8133.

UN 2010. World Population Prospects: The 2010 Revision (http://esa.un.org/wpp/) (accessed in March 2013).

De Vries, W., Kros, J., Reinds, G. J., Butterbach-Bahl, K., 2011. Quantifying impacts of nitrogen use in European agriculture on global warming potential. Current Opinion in Environmental Sustainability 3, 291-302.

Wackernagel, M., Rees, W., 1996. Our ecological footprint: reducing human impact on the earth, in: Gabriola Island, B.C., Philadelphia, P.A., ed New Society Publishers, ISBN 0-86571-312-X.

WHO, 2003. Diet, nutrition and the prevention of chronic diseases. Report of a joint WHO and FAO expert consultation, WHO technical report series 916, World Health Organization, Genève.

Xue, X., Landis, A.E., 2010. Eutrophication potential of food consumption patterns. Environmental Science & Technology 44 (16).

Table 1. Questions on the survey divided by main areas of consumption. (For original survey, see Annex I)

	Questions
Identification	Sex and the age of the person inquired
Food	How many weekly doses consumed: poultry meat, pig meat, bovine meat, milk, butter and yogurts, cheese, fish and shellfish, animal fat, mutton and goat meat, cereals (wheat), rice, other cereals (including breakfast flakes), pasta, Fruit, Beans and grain, Starchy roots, Dry fruits, Olive oil and olives, cooked vegetables, fresh vegetables, sugar and sweeteners, oil crops and spices) How many eggs eaten per week?
Drinks	How many glasses of wine drunk per week? How many glasses of alcoholic white spirits drunk per week? How many cups of coffee and/or tea drunk per week? How many glasses of beer drunk per week? How many glasses of soft drinks drunk per week?
Others	Do you smoke? If yes, how many cigarettes do you smoke per day? Is your house linked to a sewerage system with tertiary treatment of sewage?
Energy	How many KWh of electricity do you consume per month at home? How many m^3 of natural gas or gas cylinders do you consume per month at home? How many people in the household?
Transport	How many hours of plane travelled this year? How many Km travelled in public transport per week? How many Km travelled by travel by car per week? How many Km travelled in other means of transport per week? Do you have your own vehicle? If yes, what kind of fuel do you use?

Some modifications were made to the original model survey.

Table 2. Average food consumption in Portugal (data per person per year) (www.ine.pt, assessed in March 2013).

Commodity or food type	Kg/person/yr	Year of statistics
Poultry meat	35.0	2011
Pig meat	44.6	"
Cow meat	17.1	"
Milk	84.0	"
Butter and yogurts	23.0	"
Cheese	10.1	"
Fish and shellfish	57.0	2010
Animal fat	9.1	2004
Mutton and goat meat	2.4	"
Cereals (wheat)	111.9	2011
Rice	15.8	"
Other cereals including breakfast flakes	17.8	"
Pasta	6.5	2010
Fruit	112.2	2011
Beans and grains	4.1	"
Starchy roots	78.3	"
Olive oil and olives	8.6	2010
Vegetables	107.5	2004
Sugar and sweeteners	36.3	2011
Oil crops and spices	0.6	"
Eggs	8.6	"
	L/person/yr	
Wine	44.2	2011
Alcoholic white spirits	237.1	2008
Beer	53.0	2011
Soft drinks	224.1	2008
Coffee and tea	132.2	2008

Table 3. Virtual N factors for Portugal (calculated according to Leach et al., 2012)

Food type	Virtual N factor
Poultry meat	0.16
Pig meat	0.16
Cow meat	0.16
Mutton and goat meat	0.16
Animal fat	0.33
Milk (except butter)	0.32
Butter and yogurts *	0.32
Cheese	0.32
Fish and seafood	0.16
Eggs	0.31
Cereals (wheat)	0.32
Rice *	0.32
Other cereals incl. flakes *	0.32
Pasta *	0.32
Fruits	0.23
Beans and grains	0.16
Starchy roots	0.24
Dry fruits	0.16
Cooked vegetables *	0.16
Fresh vegetables *	0.32
Oil crops	0.33

*all the types of food marked, were either added or highlighted from Leach et al. (2012) original food type on the N-Calculator model survey.

Table 4. Emission factors and average energy consumption by sector and type.

Transportation	Emission factor	AVG energy consumption
Airplane (hours)	0.128000	0.31
Public transport (Km)	0.000043	26.10
Private car (Km)	0.000488	171.00
Motorcycles (Km)	0.000000	1.07

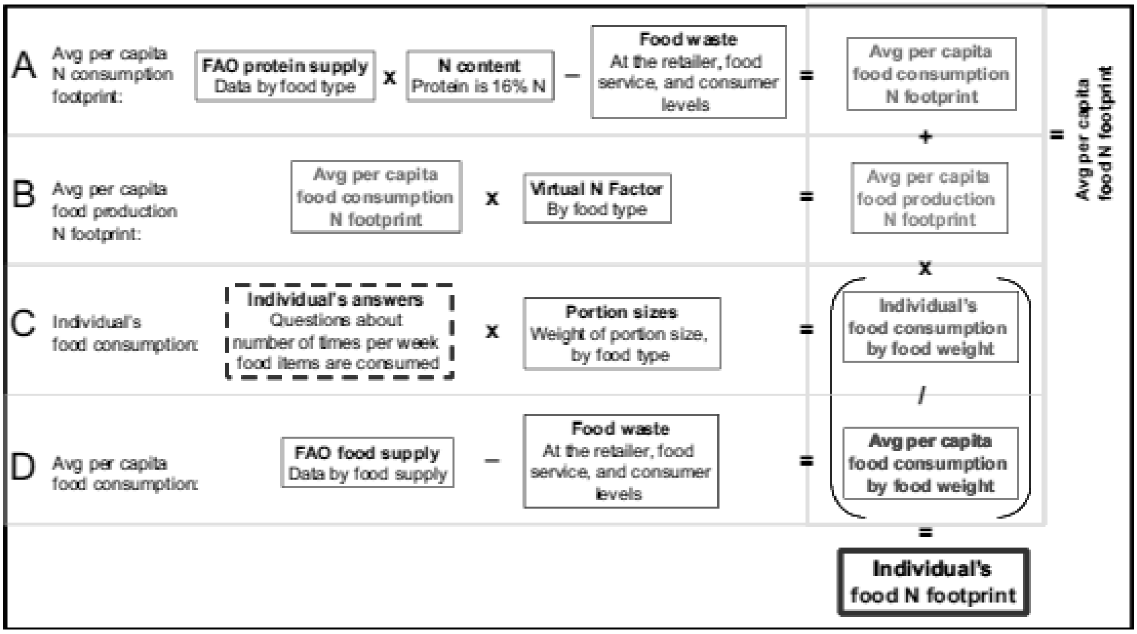

Figure 1. Schematic calculation of nitrogen footprint for food (Leach et al. 2012). This figure explains the calculation of: (A) the average per capita food consumption N footprint, (B) the average per capita food production N footprint, (C) an individual's food consumption by food weight, and (D) the average per capita food consumption, by weight, in the country. It is then shown how all of this information is used to find both a total average per capita food N footprint and an individual's total food N footprint.

Notes: (1) This figure assumes the required scaling to estimate an annual N footprint; (2) this figure is in terms of calculations by food type, but assumes the sum of all food types to find the total food N footprint; and (3) the only input required by an individual is the dashed box.

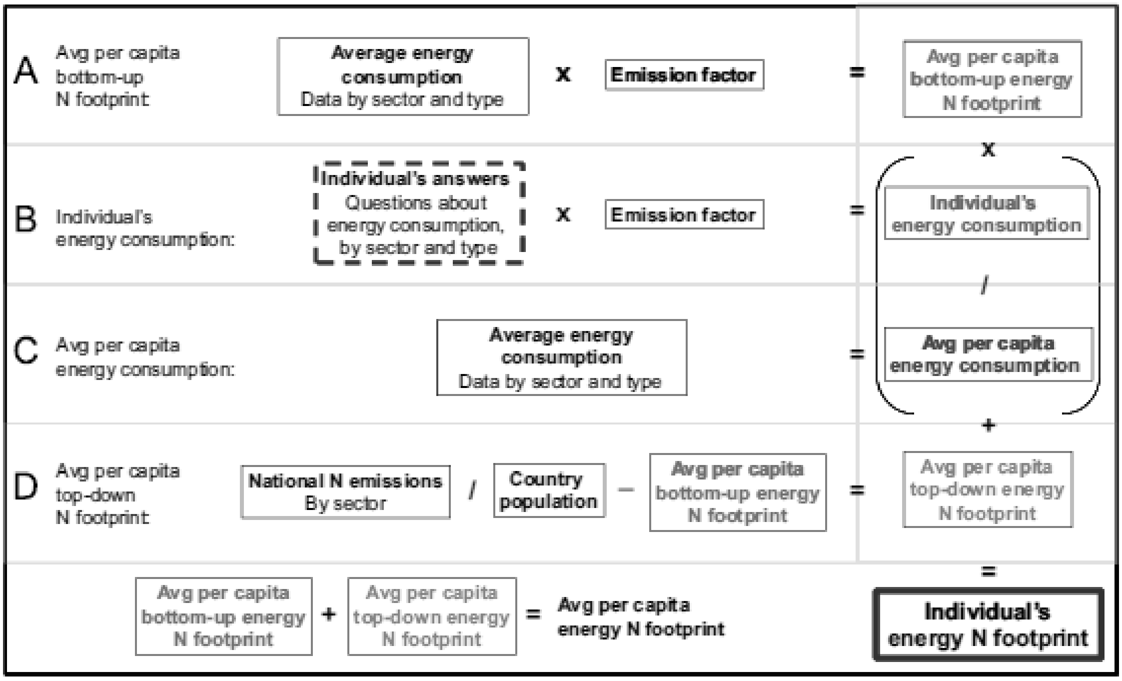

Figure 2. Schematic calculation for energy nitrogen footprint (Leach et al. 2012). This figure explains the calculation of: (A) the average per capita bottom-up energy N footprint, (B) an individual's energy consumption, (C) the average per capita energy consumption, and (D) the average per capita top-down energy footprint. It is then shown how all of this information is used to find both a total average per capita energy N footprint and an individual's total energy N footprint.

Notes: (1) This figure assumes the required scaling to estimate an annual N footprint; (2) This figure describes calculations by resource type, but assumes the summation of all resources to find the total energy N footprint; (3) The only input required by an individual is the dashed box; and (4) Two parts of the average per capita top-down N footprint (D) are scaled: (i) food energy, scaled by individual food consumption, and (ii) the goods and services sector, scaled with a question about personal spending. This is not represented in the figure.

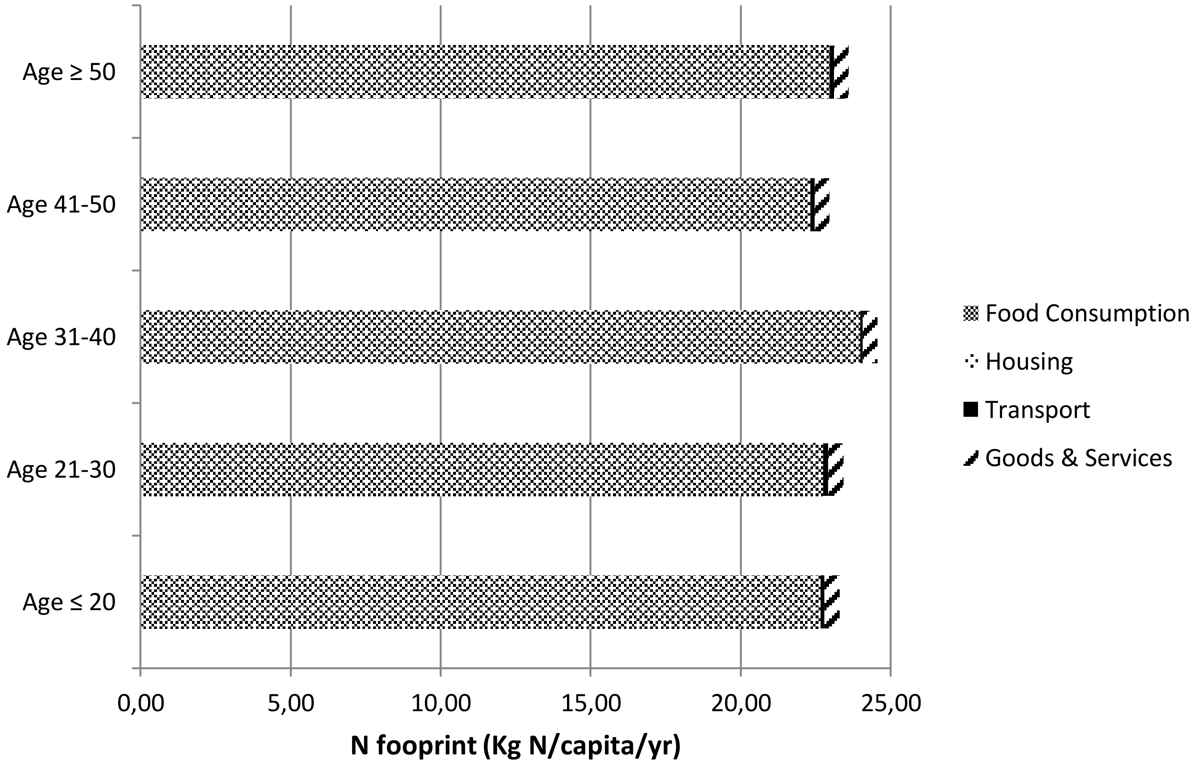

Figure 3. Nitrogen Footprint p*er capita* for different age classes. (global data on different items in annex III).

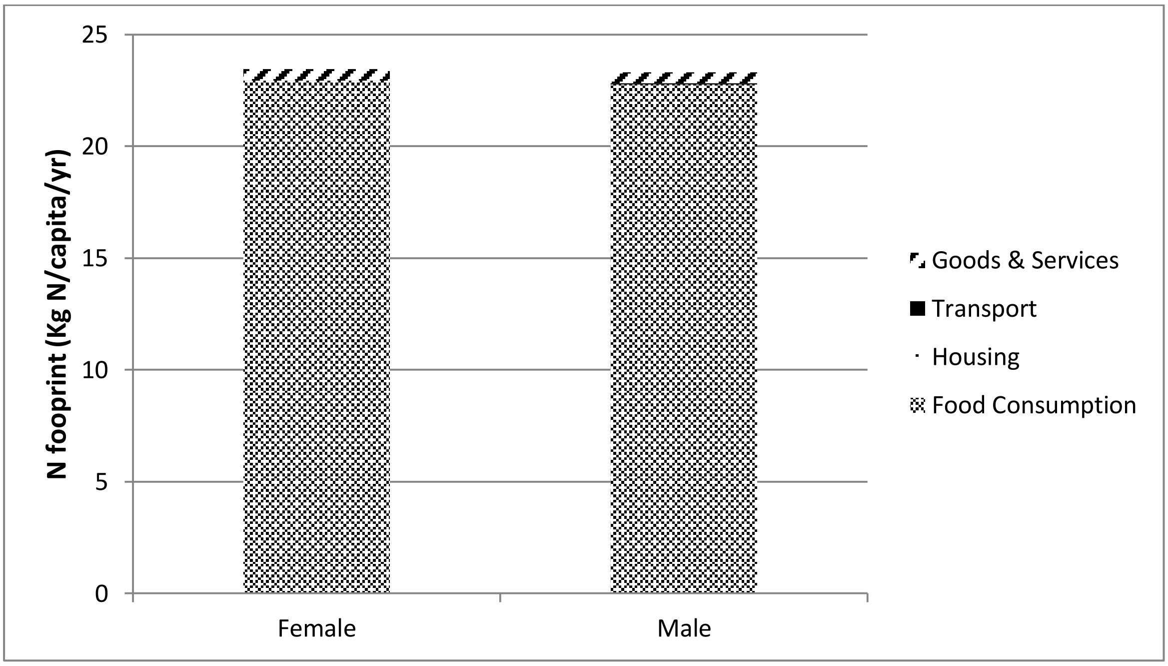

Figure 4. Nitrogen Footprint *per capita* for women and men. (global data on different items in annex III).

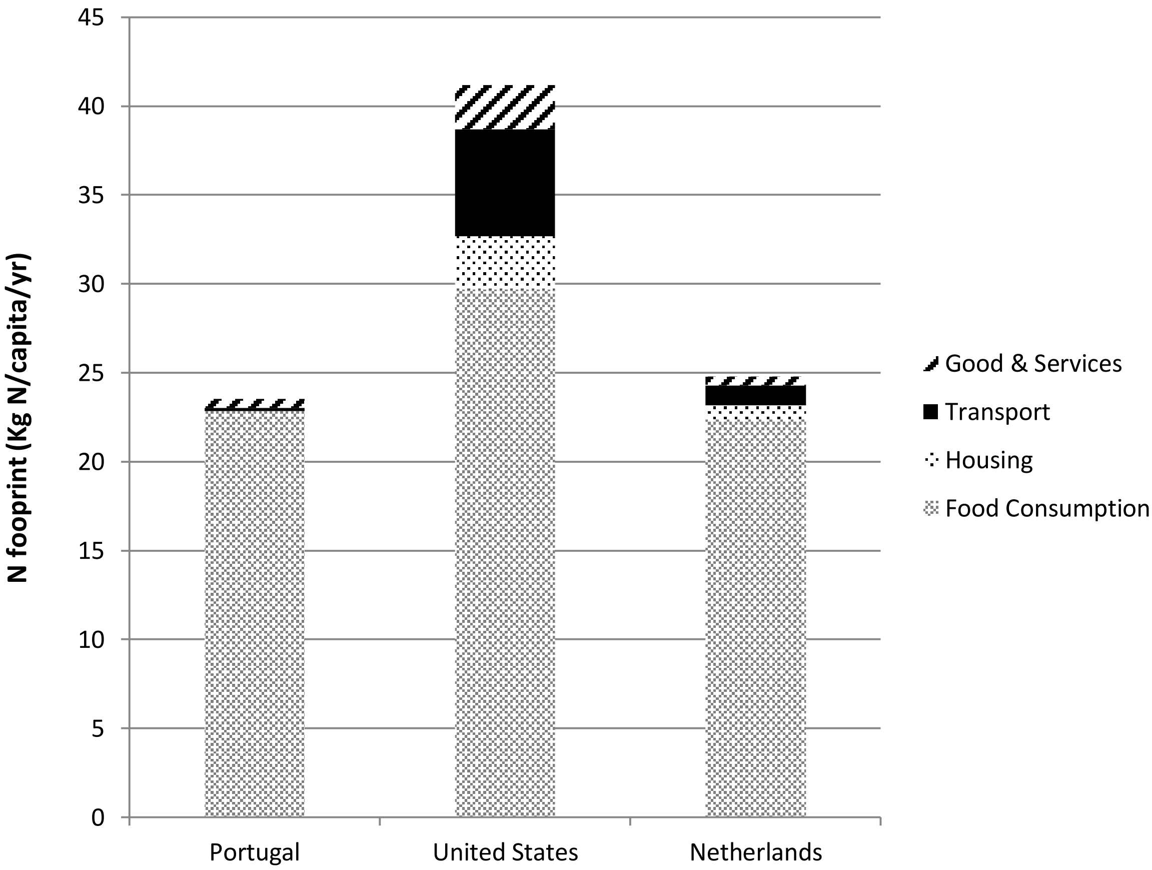

Figure 5. Comparison of Nitrogen Footprint *per capita* in Lisbon, Portugal (present sampling), and the United States of America and The Netherlands (Leach et al, 2012).

Annex I. Original Survey

Survey

N Personal Footprint

Nitrogen is a nutrient which is widely used for food and energy production and it is released into the environment in excess and accumulates beyond the assimilative capacity of Nature, thus leading to environmental pollution. Personal nitrogen footprint is an individual contribution to environment contamination with this element. With the objective of estimating average nitrogen footprint per person in Lisbon, we kindly ask you to answer these questions as accurately as possible. Thank you for your cooperation.

Sex:

Male ☐ Female ☐

Age:

☐ ≤20 ☐ 21 – 30 ☐ 31 – 40 ☐ 41 – 50 ☐ > 50

1. Food

Nitrogen footprint from food consumption includes all the nitrogen produced throughout the whole process of food production, including fertilizers, wastes, transportation and all the losses of nitrogen during this process.

1. How many times do you usually consume each type of food per week?

Animal Products

Types of food /times consumed	0	1	2	3	4	5	6	+
Poultry meat								
Pig meat								
Bovine meat								
Milk								
Butter an yogurts *								
Cheese								
Fish and selfish								
Animal fat								
Mutton and goat meat								

How many eggs do you eat per week? ☐

Vegetable Products

Types of food	0	1	2	3	4	5	6	+
Cereals (Wheat)								
Rice *								
Other cereals (including breakfast flakes) *								
Pasta *								
Fruit								
Beans and grains								
Starchy roots								
Dry fruits								
Olive oil and olives *								
Cooked vegetables *								
Fresh vegetables *								
Sugar and sweeteners								
Oil crops								
Spices								

How many glasses of wine do you drink per week? *

How many glasses of alcoholic white spirits do you consume per week? *

How many cups of coffee and/or tea do you drink per week?

How many glasses of beer do you drink per week? *

How many glasses of soft drinks do you consume per week? *

2. Do you smoke?

Yes ☐ No ☐

If yes, how many cigarettes do you smoke per day?

3. Is your house linked to a sewerage system with tertiary treatment of sewage?

Yes ☐ No ☐ I don´t now ☐

2. Energy

Your choices at home influence your nitrogen footprint because they determine the quantity of fuel combustion necessary to support your lifestyle. Electricity and natural gas used at your home require fossil fuel combustion that implies reactive nitrogen emissions to the environment.

1. How many kWh of electricity do you consume per month at home?

____

2. How many m^3 of gas or gas cylinders do you consume per month at home?

____

3. How many persons are there in your household?

____

3. Transport

The transports we use need fossil fuel combustion which are responsible for emissions of reactive nitrogen to the environment.

To fill in these questions please pay attention to the means of transport you use, as well as the average times you take them, always thinking about the short and large travels, not forgetting the daily habits and the holidays.

1. How many hours did you travel by plane this year? ☐
2. How many Km do you usually travel weekly in public transport? ☐
3. How many Km do you usually travel by car per week? ☐
4. Do you travel in any other type of transport?

   Yes ☐ No ☐

   If yes, which? ☐

   How many Km do you usually travel in this transport per week? ☐

5. Do you have your own vehicle? If yes, what kind of fuel do you use? *

   Diesel ☐ § Gasoline 95 ☐ § Gasoline 98 ☐ CNG ☐

   § specification for octane concentration

*all the types of food marked, were either added or highlighted from Leach et al. (2012) original food type on the N-Calculator model survey.

THE END

Thank you for your contribution!

Annex II. Food portion sizes for Portugal (adapted from Leach et al, 2012).

Food Type	Pt Portion Sizes (g)	Pt Portion Sizes (common units)
Animal Products		
Poultry Meat	200	200 g cooked; or 2-3 pieces of fried chicken
Pork	200	200 g cooked; or 5 slices of deli meat
Beef	200	200 g cooked; or 5 slices of deli meat; or 1 medium sirloin steak
Fish and seafood	170	170 g cooked
Milk and other dairy products	200	1 small cup of milk; or 1 small cup of yogurt or ice cream
Cheese	40	2 slices
Eggs	50	1 egg
Vegetable Products		
Wheat and other grains	100	2 small slices of bread; or 2 cups of cereal; or 1 cup of cooked pasta; or 1 bagel
Rice	180	1 cup, cooked
Vegetables	180	1 cup of vegetables; or 2 cups of green salad; or 1 cups of tomato juice
Fruits	160	1 medium piece of fruit; or 1 cup of chopped fruit
Beans and other legumes	80	½ cup cooked beans
Starchy Roots	160	1 large baked starchy roots 1cup of French fries
Nuts	60	½ cup of nuts
Coffee or tea	10	1 cup of coffee or tea
Alcoholic beverages	200	One 333 mL beer; or One 150 mL glass of wine

Annex III. Results from the surveys conducted. These data represent the average values obtained by product type and energy consumed by the Portuguese.

Number of surveys per sex

% Male	43
% Female	57

Number of surveys per age class

% Age ≤20	7
% Age 21-30	36
% Age 31-40	8
% Age 41-50	12
% Age ≥50	37

Average values obtained from survey to the animal and vegetable products and drinks

Animal Products	Portions *per* week
Poultry Meat	2.77
Pig meat	1.88
Bovine Meat	2.00
Milk	4.67
Butter & Yogurts	5.05
Cheese	3.73
Fish and seafood	3.03
Animal fats	0.39
Mutton and goat meat	0.20
Eggs	2.51

Drinks	Portions *per* week
Glasses of wine	2.23
Glasses of alcoholic beverages	0.77
Cups of coffee or tea	13.08
Glasses of beer	1.50
Glasses of soft drinks	3.57

Vegetable Products	Portions *per* week
Cereals (Wheat)	5.10
Rice	3.60
Other cereals (inc. flakes)	2.22
Mass	2.76
Fruits	5.42
Beans & grains	1.89
Starchy Roots	3.36
Dry fruits	1.37
Oil and olives oil	5.66
Vegetables cooked	3.91
Fresh vegetables	3.94
Sugar & sweeteners	4.68
Oil crops	1.72
Spices	3.51

Number average of cigarettes smoked per person per day

Tabaco	
Number of cigarettes	3.07

Number of surveys per sewerage system with tertiary treatment of sewer

House linked to a sewerage system with tertiary treatment of sewer	95%
House not linked to a sewerage system with tertiary treatment of sewer	5%

Number of persons in household

Household	2.89

Average values obtained from survey to housing and transport

Housing	
Electricity (Kwh/month)	221.12
Natural gas (m^3/month)	13.47
Gas cylinder (m^3/month)	1.25

Transport	
Airplane (Hours/year)	3.72
Transp. Public (Km/week)	85.46
Car (Km/week)	203.09
Motorcycles (Km/week)	1.60

Number of surveys per type of fuel (percentage of use)

Fuel	Percentage
Gasoline	34%
Diesel	41%
GPL	1%
Without car	24%

Annex IV. Excel table used to calculate the N Footprint (Animal products)

Animal Products	Survey	Portions (*g*)	FAO Food supply (*Kg/cap/year*)	Protein supply (*g/cap/day*)	Protein supply (K*g/cap/year*)	N supply (*Kg/cap/Year*)	Food Waste (% wasted)
Poultry Meat	2.77	200	28.70	11.80	4.31	0.69	0.11
Pig meat	1.88	200	42.90	11.50	4.20	0.67	0.11
Bovine Meat	2.00	200	18.30	7.50	2.74	0.44	0.07
Milk	4.67	200	206.30	17.60	6.42	1.03	0.33
Butter &Yogurts	5.05	200	2.20	0.10	0.04	0.01	0.00
Cheese	3.73	40	9.10	6.30	2.30	0.37	0.12
Fish and seafood	3.03	170	61.10	16.30	5.95	0.95	0.15
Animal fats	0.39		13.50	0.20	0.07	0.01	0.00
Mutton & goat meat	0.20	200	2.40	0.80	0.29	0.05	0.01
Eggs	2.51	50	9.30	2.90	1.06	0.17	0.05
Subtotal			393.80	75.00	27.38	4.38	0.95

Annex IV. Excel table used to calculate the N Footprint (Vegetable products)

Vegetable Products	Survey	Portions	FAO Food supply (*Kg/cap/year*)	Protein supply (*g/cap/day*)	Protein supply (Kg/cap/year)	N supply (Kg/cap/*year*)	Food Waste (% waste)
Cereals (Wheat)	5.10	100	104.90	24.50	8.94	1.43	0.46
Rice	3.60	180	14.80	2.80	1.02	0.16	0.05
Other cereals (inc. flakes)	2.22	50	140.50	31.00	11.32	1.81	0.58
Pasta	2.76	180	140.50	31.00	11.32	1.81	0.58
Fruits	5.42	160	125.90	1.80	0.66	0.11	0.02
Beans & grains	1.89	80	3.30	1.90	0.69	0.11	0.02
Starchy Roots	3.36	160	69.80	2.80	1.02	0.16	0.04
Dry fruits	1.37	60	4.60	0.60	0.22	0.04	0.01
Oil and olives oil	5.66		2.90	0.30	0.11	0.02	
Vegetables cooked	3.91	180	187.20	5.90	2.15	0.34	0.06
Fresh vegetables	3.94	180	187.20	5.90	2.15	0.34	0.11
Sugar & sweeteners	4.68		27.60	0.00	0.00	0.00	
Oil crops	1.72		21.40	0.10	0.04	0.01	0.00
Spices	3.51		0.20	0.00	0.00	0.00	
Subtotal			1030.80	108.60	39.64	6.34	1.92

Annex IV. Excel table used to calculate the N Footprint (Drinks)

Drinks	Survey	Portions	FAO Food supply (*Kg/cap/year*)	Protein supply (*g/cap/day*)	Protein supply (Kg/*cap/year*)	N supply (K*g/cap/year*)	Food Waste (% wasted)
Glasses of wine	2.23	200	38.10	0.00	0.00	0.00	
Glasses of alcoholic beverages	0.77	200	97.10	0.70	0.26	0.04	
Cups of coffee or tea	13.08	10	6.50	1.20	0.44	0.07	
Glasses of beer	1.50	200	50.90	0.70	0.26	0.04	
Glasses of soft drinks	3.57	200			0.00	0.00	
Total			192.60	2.60	0.95	0.15	0.00